

Quality assurance test of readout chips and pixel sensor hybrids for PHENIX

M. Kurosawa, Y. Akiba, J. Asai, B. Deepak, H. En'yo, K. Fujiwara, R. Ichimiya, J. Kanaya, M. Kasai, M. Kawashima, R. Muto, M. Okumura, Y. Onuki, P. Riedler, and A. Taketani

The PHENIX detector at RHIC-BNL has been upgraded with a silicon vertex tracker (VTX)¹⁾ surrounding a beam pipe with four cylindrical layers. The inner two layers are silicon pixel detectors (SPDs) and the outer two layers are silicon strip detectors (SSDs). In the plan of upgrading PHENIX VTX, the RIKEN group is developing the SPD. The SPD is made up of 30 ladders, each of which consists of four sensor hybrids.²⁾ A sensor hybrid is an assembly of a silicon pixel sensor and four readout chips³⁾ (ALICE1LHCb) bump-bonded with 20- μm -diameter bumps to the sensor (bonded by VTT^{a)}). The readout chip has 8192 pixel cells arranged in 32 columns and 256 rows. The pixel size is 50 μm \times 425 μm . In preparation for the mass production of the ladder, a quality assurance (QA) test is required for the readout chips and pixel sensor hybrids to ensure that they can be used as detectors. This report describes recent results of the QA test.

Figure 1 shows a picture of the QA system. It mainly consists of a probe station (SUSS MacroTec), a probe card, a DAQ adapter board, VME equipment for a DAQ system, and a Windows PC. A LabVIEW program running in the Windows PC is used for data taking and analysis. The measured and analyzed data are sent to a PostgreSQL database server located at a secure area accessible only from the internal RIKEN network. The database can be accessed from the web interface in the secure area.

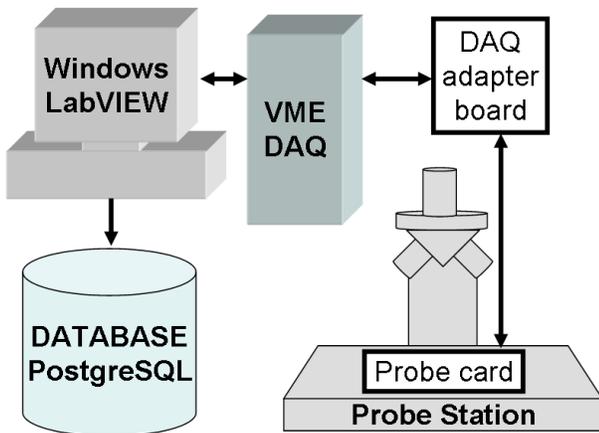


Fig. 1. QA test system in a clean room at RIKEN.

All the readout chips and hybrid sensors are tested

*1 Tokyo Metropolitan College of Aeronautical Engineering
 a) VTT Electronics, Tekniikantie 17, Epsoo, P.O. Box 1101, FIN-02044 Epsoo, Finland

for the following parameters.

Items to be checked for readout chips:

- (1) Current consumption
 - The current consumptions of analog and digital circuits of the readout chips are measured.
- (2) JTAG and DAC functionality
 - It is confirmed whether configuration settings in the chip are readable and writable by means of a Joint Test Action Group (JTAG) protocol.
 - The digital-to-analog converter (DAC) linearity is calibrated.
- (3) Mask functionality
 - The noisy pixels can be masked by a mask functionality.
- (4) Minimum threshold and noise level
 - The minimum threshold in all pixel matrices is determined.
- (5) Mean threshold and mean noise for the complete pixel matrix
 - The test pulse from the pulsar inside the chip is sent to each pixel cell and the mean threshold and noise levels are determined.

Items to be checked for sensor hybrids:

- (1) Same tests as those in items 1, 3 and 4 and part of JTAG functionality test in item 2
 - The sensor is biased at 50 V during the measurements.
- (2) Performance of SPD with β source (⁹⁰Sr)
 - Faulty bump bonds and maximum efficiency are checked by β source measurement.

The tested readout chips and sensor hybrids are classified in three classes, Class I, II, and III. The chips and sensor hybrids classified as Class I are used for the experiment. Class II and III are not used for the experiment, but Class II is used for other purposes such as the production of a prototype ladder.

The readout chips (sensor hybrids) categorized into Class I satisfy the following criteria.

- Current consumptions lower than 350 and 270 mA for analog and digital circuits, respectively.
- A complete JTAG and DAC functionality for readout chips and a complete JTAG functionality for sensor hybrids.
- Mean threshold lower than 1800 electrons (4200

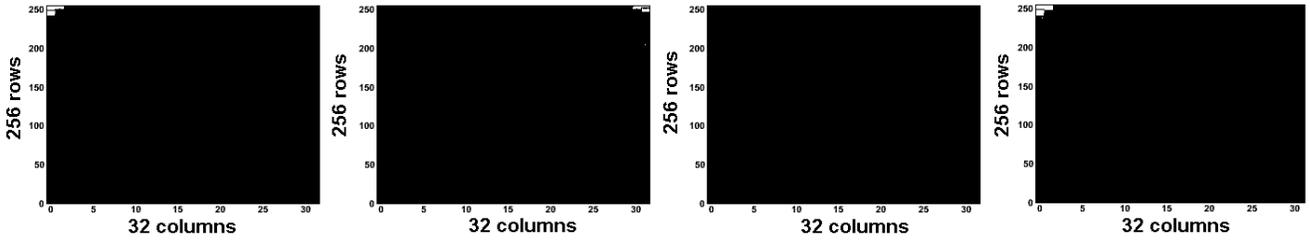


Fig. 2. Typical response of a sensor hybrid, categorized into Class I, to β rays. Good and faulty bump bonds are shown in black and white, respectively.

electrons).

- Less than 1% defect pixels in mean threshold scan (and source test).

The QA test results of the readout chips are summarized in Fig 3. About 1030 Class I readout chips of them were used for bump-bonding with a pixel sensor. The average of the mean threshold and mean noise for the Class I readout chips are about 1400 and 120 electrons, respectively.

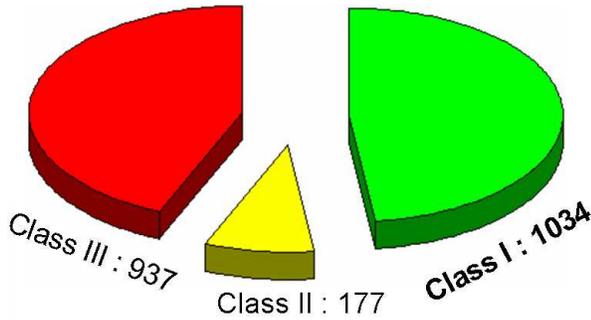


Fig. 3. QA test results of the readout chips.

Figure 4 shows the summary of QA test results. About 100 sensor hybrids have been probed and 45 Class I sensor hybrids were obtained. The average of the mean threshold and the mean noise for the Class I sensor hybrids are about 3300 and 150 electrons, respectively. A typical response to β rays from ^{90}Sr is shown in Fig. 2.

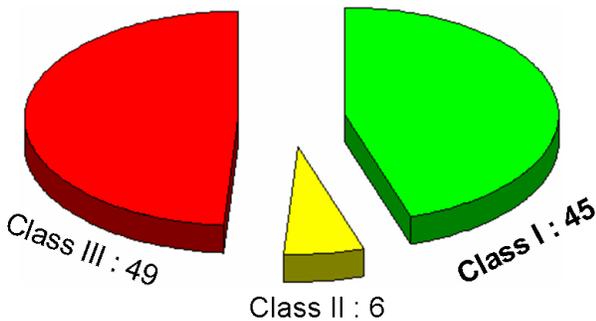


Fig. 4. QA test results of the sensor hybrids.

The main reasons of classification in Class III were a mask test error and a faulty bump-bonding, and one or two readout chips out of four readout chips on the sensor had these errors. Such Class III sensor hybrids can be repaired by a replacing bad readout chips with new ones (rework process).

We obtained 1030 readout chips and 45 sensor hybrids classified as Class I. Since a total of 120 sensor hybrids are required for the experiment, we need 75 Class I sensor hybrids more. About 50 sensor hybrids will be fabricated and 38 Class III sensor hybrids will be repaired by the rework process to obtain 75 Class I sensor hybrids. The required time of QA is about 18 sensor hybrids per month. The QA test of the required sensor hybrids for the experiment will be completed by August 2008.

References

- 1) Y. Akiba et al.: RIKEN Accel. Prog. Rep. **41**, xxx (2008).
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- 3) K. Fujiwara et al.: RIKEN Accel. Prog. Rep. **38**, 228 (2005).